Redesign and Improved Performance of the Tropospheric Ozone Lidar at Table Mountain

I. Stuart McDermid, Georg Beyerle, David Haner, and Thierry Leblanc.
Jet Propulsion Laboratory, California Institute of Technology, Table Mountain Facility, Wrightwood, CA 92397-0367, USA.

Abstract. We describe improvements to, and results from a lidar system for measurements of ozone profiles in the troposphere and lower stratosphere. The changes were primarily related to the optical receiver sub-systems and the data acquisition system. The goals of these modifications were to increase the spatial and temporal resolution of the lidar, to extend the altitude range covered, and to improve the quality of the results.

Ozone Lidar

Previously, a combined lidar system was operated at the Jet Propulsion Laboratory (JPL), Table Mountain Facility (TMF, 34.4°N, 117.4°W) for atmospheric measurements of both ozone and aerosols in the troposphere and lower stratosphere [*McDermid et al.*, 1991]. This dual role caused many problems and compromises, and limited the performance of the lidar. Here we describe a new system implemented solely for ozone measurements.

The laser transmitter for the ozone DIAL system is essentially unchanged from that described by McDermid et al [1991]. The DIAL wavelengths are generated by stimulated Raman shifting of the Nd:YAG fourth harmonic (266 nm) in D_2 (289 nm) and/or HD (294 nm) and/or H_2 (299 nm). While any pair of these wavelengths can be used the results described here were obtained using 289 and 299 nm. The laser is a 10 Hz dual-beam system and the two output wavelengths are generated and transmitted simultaneously. To reduce the laser divergence, as is required because of the small field-of-view (FOV) of the telescope, refractive beam expander telescopes with a magnification of 5 are used after the Raman cells.

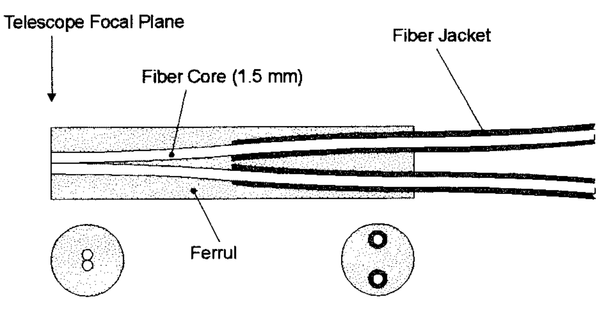

Figure 1. Dual fiber arrangement mounted at the telescope focus.

The receiver telescope was replaced with a Newtonian configuration utilizing a 0.9 m diameter mirror with a focal length of 2.5 m. This increased the light gathering capacity by more than a factor of five. The telescope structures were designed and built at TMF with the focal plane optics being supported by a hexapod structure [*Steinbach et al.*, 1995; *Sandia Hexapod Project*].

A novel dual-fiber arrangement is mounted at the telescope focus as shown schematically in figure 1. In this arrangement the fiber jacket is stripped away at the ends so that the fibers can be placed very close together, essentially touching. The fiber core diameters are 1.5 mm and are used as the effective field-stops at the telescope focus. Figure 2 shows the resulting FOV projected into the atmosphere. Each fiber views a different region in the atmosphere but because the FOV is only 600 μrad these regions are small and close together.

This arrangement provides the primary step in separating the two DIAL wavelengths. The transmitted beams are each aligned to one particular fiber. Since the laser divergence is much less than the FOV the beams are well separated in the atmosphere. One advantage of this method of separating the different wavelengths spatially is that it is wavelength independent and it allows us to change DIAL wavelength pairs more easily. This technique reasonably assumes that the atmosphere is homogeneous through the different volumes probed by each beam and/or that movement of the atmosphere during the integration time will act to average out any differences.

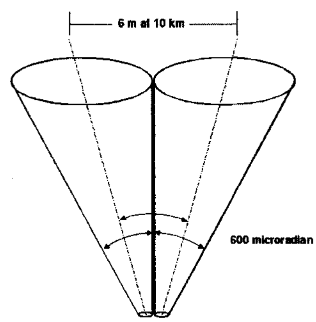

Figure 2. Schematic of the fields-of-view of the twin fibers, projected into the atmosphere.

Returns from close range are collected by two separate small telescopes with 50 mm apertures that focus the laser backscatter onto 400 micron diameter fibers. Each of these small telescope is aligned independently to one of the output laser beams. Thus, the lidar signal is divided into four fibers; near-range λ(1) and λ(2), and far-range λ(1) and λ(2). The fibers are then brought to a rotating chopper as shown in figure 3.

The chopper wheel rotates at 6000 rpm and the radii to the fiber positions are 160 mm for the near-range fibers and 100 mm for the far-range. The near- and far-range chopping positions are staggered such that the far range opens up at approximately 5 km higher altitude. Adjustment is provided so that this offset can be both varied and set precisely. At the near-range fiber positions the blade speed is ~100 $m.s^{-1}$ and therefore the time to move across the 400 μm fiber is 4 μs, i.e., <1 km. This fast transition is required in order to get the near channels open as soon as possible while still blocking the returns from the boundary laser and scattered laser light within the laboratory.

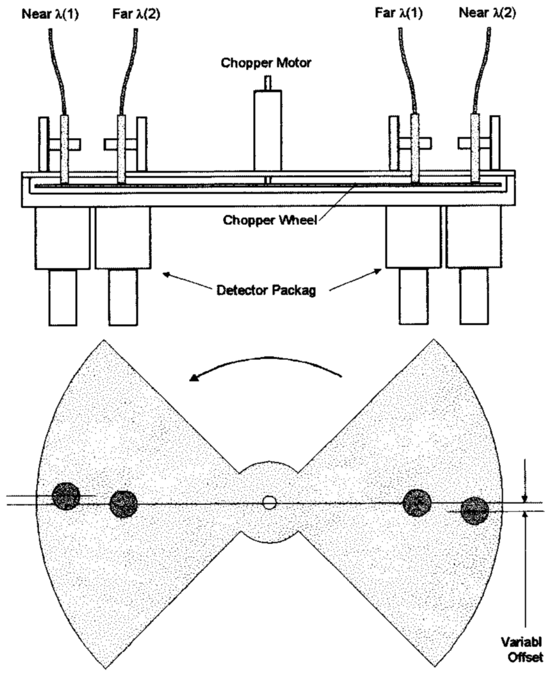

Figure 3. Chopper wheel, fiber, and detector arrangement for the ozone DIAL.

A detector package is attached to the rear of the chopper housing. This package incorporates, first, a narrowband filter which reflects the UV light at the laser wavelengths and transmits everything else. This is followed by a collimating lens and a narrowband interference filter. Then, the light is refocused onto a metal-can photomultiplier (Hamamatsu). Signals from the photomultipliers are then amplified and input to a four channel, combined transient recorder/photon counting system (Licel).

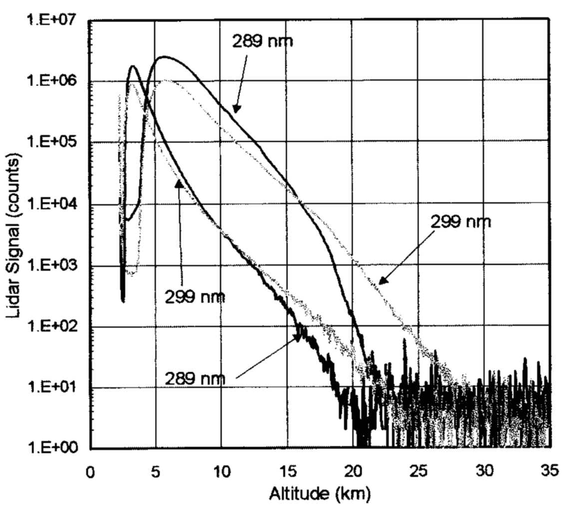

Figure 4. Lidar signals, March 19, 2000 (UT).

As an example of the results obtained by this lidar system, figure 4 shows the raw data and figure 5 the derived ozone profile measured on the evening of March 19, 2000. Of particular note is the dynamic range of the lidar signals, which extend over six decades, and the low background signal. These profiles are typical of those obtained by this lidar for nighttime measurements. The upper altitude limit is set by the extinction of the laser radiation by the increasing concentration of ozone above 20 km; the 289 nm beam is completely extinguished by the ozone layer as can clearly be seen in figure 4. To reach higher altitudes a second DIAL system using longer wavelengths, 308 and 355 nm, is used. The integration time for these profiles was ~2 hours; however, much shorter times can be used to reach lower altitudes.

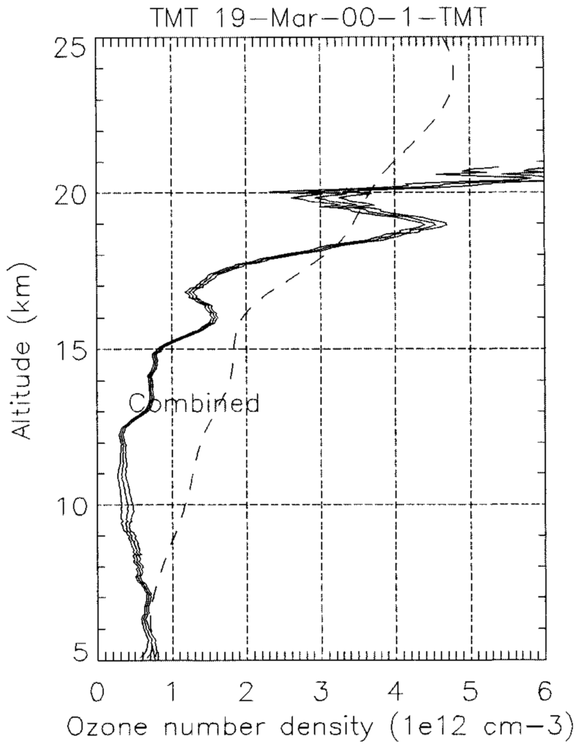

Figure 5. Tropospheric ozone profile derived from the raw data in figure 4.

Acknowledgements

The work described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under an agreement with the National Aeronautics and Space Administration.

References

McDermid, I. S., D. A. Haner, M. M. Kleiman, T. D. Walsh and M. L. White, "Differential Absorption Lidar Systems at JPL-TMF for Tropospheric and Stratospheric Ozone Measurements," *Opt. Eng.*, *30*, 22-30,1991.

Sandia Hexapod Project http://java.ca.sandia.gov/imtl/hexapod/hexapod.html

Steinbach, M., U. Bräuer, H. Fischer, C. Hüllenkremer, H.-D. Kleinschrodt, W. Mildner, R. Ponzer, H.-J. Schäfer, G. Sesselmann, F. Theopold, "Special features of large lidar telescopes, Lidar and atmospheric sensing," *Proc. SPIE*, *2505*, 66-74, 1995.